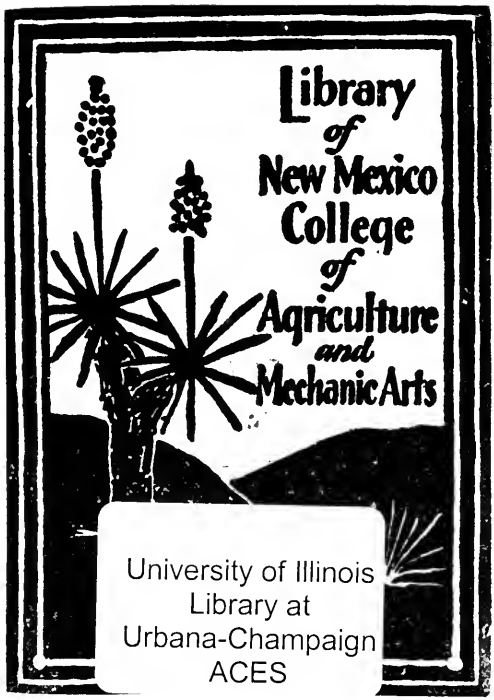

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

BULLETIN No. 130

EXPERIMENTS WITH REPELLENTS AGAINST THE CORN ROOT-APHIS, 1905 AND 1906

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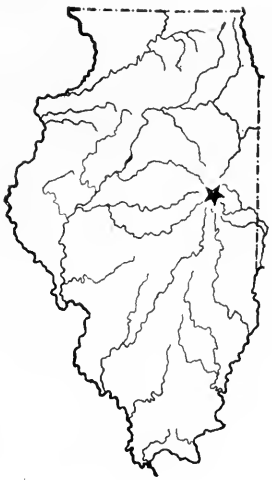

URBANA, ILLINOIS, DECEMBER, 1908

Summary of Bulletin No. 130

1. Thirty minutes' soaking of seed-corn in kerosene before planting, injured seed but protected plants against root-aphis in preliminary field experiment made in 1905. Pages 4–5

2. Summer plot-plantings made in 1905, with seed treated with kerosene, kerosene emulsion, coal-tar water, or turpentine, showed no injury after a moderate use of kerosene and coal-tar water. Results with kerosene emulsion and with turpentine were conflicting. Pages 5–8

3. Indoor pot-plantings in 1906 showed no injury after a moderate use of kerosene, oil of lemon, carbolic acid, formalin, lysol, chlorid of lime, carbon bisulphid, tobacco water, or camphor. Soaking in common alcohol for 30 minutes or in wood alcohol for 20 minutes, injured the seed. Tests made of various other substances. Pages 9–15

4. Extensive field experiments were made in 1906 with minimum quantities of oil of lemon, kerosene, formalin, and carbolic acid applied to seed just before planting. Examination six weeks after planting showed average diminution of number of root-lice, and of hills infested by them, as follows: oil of lemon, 76 percent; kerosene, 57 percent; formalin, 49 percent; carbolic acid, 8 percent. Ten weeks after planting, corn in the experimental plots averaged 72 percent taller than in checks. Examined 19 weeks after planting, applications made to the seed were found to have increased the number of ear-bearing stalks to the acre as follows: oil of lemon, 1159; carbolic acid, 945; formalin, 742; kerosene, 274. Pages 15–23

5. The increase in root-lice in the field was seven-fold in twenty-three days—equal to nearly 3 millions to 1 between April 1 and October 1. Page 21

6. In a small special test, made by planting a few hills of corn close around nests of ants in the field, kerosene and carbolic acid kept the insects away from the corn, but oil of lemon, formalin, and several other substances tested, were without effect. Pages 24–26

7. General procedure recommended as protection to corn against root-aphis. Pages 26–28

EXPERIMENTS WITH REPELLENTS AGAINST THE CORN ROOT-APHIS, 1905 AND 1906

By STEPHEN A. FORBES, State Entomologist

The corn root-aphis, a minute, bluish green, sluggish, soft-bodied insect found on the roots of corn, is one of the most destructive and dangerous insect pests of the corn plant. Beginning as soon as the kernel sprouts to suck the sap from the young roots, it may continue its injury without interruption until frost, unless the infested plant in the meantime perishes. It has an enormous power of multiplication, producing, under favorable circumstances, as many as sixteen generations in a season, and it is capable of spreading from field to field rapidly on the wing, many of each generation, except the first of the year, having the power of flight.

Altho a peculiarly sluggish and stupid insect, wholly unable to make its own way unaided, it has always in its service one of the most capable, abundant, active, and persistent of our common insect species. This is the so-called corn-field ant (*Lasius alienus americanus*), in whose charge the corn root-aphis is usually found, and by which its eggs, laid in fall, are carried thru the winter. This corn-field ant has no power of injuring the corn directly, except as it may occasionally, or under peculiar circumstances, devour the softened kernel in the earth, and the root-aphis, left to itself, can not even get access to its food in numbers to do any noticeable harm; but the two in partnership check the growth of the plants, and even kill outright whole fields of corn, the aphis making the destructive attack, and the ant protecting, transporting, and guarding the aphis, and collecting, preserving, and hatching its eggs.

The practical control of this pair of insects is especially important because the injury done to corn, already very heavy, is sure to increase with time. The more generally and continuously corn is grown, and the more the soil deteriorates under continuous cropping, the greater this aphis injury must become. It is hence most serious and threatening in those very parts of our area best adapted to corn, and is much the greatest now in Illinois in the central part of the state, where corn is the principal crop.

Neither of these insects is subject, so far as known, to destruction by parasites or by contagious diseases, the principal natural checks on the multiplication of most other injurious species. About the only natural agency which can be depended on to reduce the numbers of the corn root-aphis is a long-continued soaking of the ground by frequent heavy rains, especially if these come in a slow, cool spring. The very wet spring of 1907, for example, seems to have had the effect to

drown out the root-lice and also, to some extent, the maggotlike young of the ants under ground; and some fields heavily enough infested in April and early May of that year to make a profitable crop very unlikely, were completely cleared of root-lice by the beginning of June, and contained unusually few ants.

Our later work on the ant-aphis problem has been done mainly on two lines. We have attempted to test, by field experiments, the value of a repeated deep and thoro stirring of the soil previous to planting, and we have experimented with offensive applications to the seed, of a kind to last a considerable time in the ground, and to keep the ants, and consequently the aphids, out of the hills as long as possible while the plant was still young and especially sensitive to injury. Experiments of the first class were reported in Bulletin 104 of the Agricultural Experiment Station published in October, 1905, and again in the Twenty-fourth Report of the State Entomologist, pages 8 to 29; but those with repellents applied to the seed in 1905–06 are here fully reported for the first time.

REPELLENT APPLICATIONS TO THE SEED

My attention was first called to the fact that applications to the seed might serve to protect young corn against root-louse attack by statements occasionally made by farmers who had treated their seed-corn with kerosene or turpentine just before planting.* Having, I must confess, very little faith in this treatment, I nevertheless directed an assistant, Mr. E. O. G. Kelly, in charge of my field work in 1905, to test the effect of kerosene used in this way, and as part of a general field experiment for the protection of corn against aphis injury, he planted a small plot in an experimental field with seed which had been soaked in kerosene for half an hour.

The effect of this treatment was a double surprise to us. In the first place, only about half as much of the corn grew as in other experiments made in the same field with seed from the same lot, serving, consequently, as checks on this; the other half swelled up with the moisture absorbed, but never sprouted. Furthermore, germination was delayed, growth of the young corn was slow at first, and many of the plants were dwarfed and crippled, the growing tip or plumule of the plant making its way with great difficulty out of the inclosing sheath (the coleophyl) which protects it as it grows upward thru the earth. In the second place, altho the field of corn of which this planting was a part was heavily infested and noticeably injured by the corn root-aphis, this special plot, when examined some weeks after planting, was found to be almost wholly free from the aphis, and to contain but few ants; and at husking time its yield equaled in quantity and excelled in quality that of like areas in other parts of the same field. The treatment of the seed had evidently so repelled the ants

*See especially my address on the corn root-aphis in the Tenth Report of the Illinois Farmers' Institute, p. 49.

and aphids that protection from their injury had more than compensated for the original poor stand. It thus became our problem so to modify this treatment as to get the beneficial result without risk of the injury.

It was evident enough that kerosene merely applied to the seed could act only by reason of its persistent odor—peculiarly offensive to ants—and it seemed quite probable that corn might be so treated with this or some other strong-smelling substance that ants would be kept out of the hills for a considerable time and that the seed would not be injured. As a test of substances possibly useful for this purpose, a long series of experimental plantings was made, from June to August, 1905, and from February to July, 1906, in the field, at Urbana, and in the insectary connected with my office there, and a careful record was kept of the percentage of kernels germinating in each planting, and of the condition of the corn plants for several days after they appeared above ground. The substances thus tested as to their effects on corn were kerosene, kerosene emulsion, crude petroleum, turpentine, carbolic acid, formalin, oil of lemon, oil of wintergreen, oil of cloves, oil of sassafras, wood alcohol, common alcohol, coal-tar. coal-tar water, carbon bisulphid, chlorid of lime, kainit, flowers of sulphur, lime, salt, various compound solutions of sulphur, lime, and salt, and of sulphur, lime, and blue vitriol, copper sulphate, iron sulphate, mustard, camphor, musk, lysol, tobacco-water, the proprietary insecticides known as "Scalecide," "Con Sol," "Calcothion," and "Fruitolin," and the so-called "Rex Dip."

PLOT EXPERIMENTS, 1905

For this purpose the use of a plot of ground was obtained in June, 1905, on the farm of the Experiment Station at Urbana, on which the corn was planted in rows by hand, usually two grains to the hill. Fifteen thousand five hundred kernels were planted in this plot, 5750 of them after treatment with kerosene, 2050 with kerosene emulsion, 2000 with tar-water, 3650 with turpentine, and 2050, with no special application, serving as checks. The principal plantings were those made June 15, of 1500 kernels, and June 28, of 12,500 kernels. Smaller additional plantings, varying from 50 to 1000 kernels, were made June 29 and 30, July 18 and 21, and August 9.

The results of the planting of June 15 were determined by an inspection June 26, and those of June 28 were determined July 20—the first, eleven days after planting. and the second after twenty-two days. The weather of these two intervals differed materially, that between June 15 and June 26 being rather dry, and that between June 28 and July 20 decidedly wet—a fact to be borne in mind at some points in comparing the two series of experiments. The ground must have been fairly moist, however, June 15, since a rain of 1.05 inches had fallen on the 10th, but the only rain to fall during the eleven days following June 15 was .06 of an inch on the 20th. Between the 28th of June and the 20th of July, on the other hand, rain fell on sixteen days, to

the total amount of 5.34 inches—that of one day, July 5, amounting to 1.44 inches.

Treatment of seed with kerosene.—The seed-corn experiment with kerosene was so varied as to bring into comparison the results of simply dipping the seed and planting immediately afterwards, and of soaking it for 5 minutes, 10 minutes, 20 minutes, and 30 minutes, and for 11 days, 20 days, and 41 days. Tests were likewise made of the effect of first soaking the seed in water before putting it into kerosene.

The checks to these experiments—2050 kernels which were planted in ten lots of 50 to 500 kernels each at several dates between June 15 and July 21—germinated in ratios ranging from 83 to 96 percent, with an average of 89; and with this average, of course, the germination ratios of the various experiments are to be compared.

Eight experimental lots, containing 2225 kernels in all, received the simplest treatment—a mere dipping in kerosene immediately before planting. The ratios of germination for seven of these lots varied from 84 to 97, with an average of 91. The eighth lot, of only 50 kernels planted in earth kept continuously moist, gave a germination ratio of 62 percent, and including this the average for the series is 87.6. It may fairly be said, consequently, that injury by this treatment was practically imperceptible, but that a suspicion is created of possible damage to the seed if the weather is continuously wet after planting.

Eight lots of seed, numbering 2225 kernels in all, were soaked in kerosene for 5 minutes just before planting. Here also no perceptible damage was done to the seed, the germination ratio amounting to 88.8, to be compared with 89 for the checks.

Of eleven additional lots, averaging 100 kernels each, soaked in kerosene for periods varying from 10 to 30 minutes, 85.2 percent grew, the ratios ranging from 78 to 96. We begin to see here evidences of slight but obvious injury to the seed as a consequence of the treatment. It is nevertheless puzzling to find that 89 kernels grew out of 100 kernels soaked for 11 days, and that 86 percent of 50 kernels soaked for 20 days and 80 percent of the same number soaked for 41 days, also grew.

In many of these kerosene experiments, even tho the kernels sprouted eventually and plants appeared above ground, the germination was much retarded and the plants were more or less distorted and deformed—an effect returned to on a later page of this article.

Kerosene emulsion.—For some obscure reason the result of the treatment of 400 kernels with kerosene emulsion June 15, was very much less favorable than that of 1500 kernels planted June 28. In the first experiments the seed was soaked for 30 minutes in emulsion diluted to contain 10 per cent, 20 percent, 40 percent, and 50 percent of kerosene, with the effect to give a germination ratio, eleven days after planting, of 46 percent for the first, 76 for the second, 63 for the third, and 57 for the fourth of these lots, or an average of 60.5 percent to grow from these plantings. June 28, emulsions were used containing 10, 20, and 40 percent of kerosene, in which corn was soaked for 30 minutes, each of three lots containing 500 kernels. The percent-

ages to grow varied from 91.6 to 95.8, with an average of 93. I am unable to explain these discrepancies, and consequently can not attach any especial importance to these experiments with kerosene emulsion.

Turpentine.—A like discrepancy appears in the turpentine experiments, four plantings for which were made June 15, and six plantings June 28. The first, of 100 kernels each, averaged 56½ percent to grow, and the second, of 500 kernels each, averaged 88 percent. In the plantings of 100 kernels made June 15 immediately after dipping in turpentine, 28 percent grew; while of another hundred soaked in turpentine for 5 minutes, 76 percent grew. Of a third lot, soaked for 10 minutes, 95 percent grew; and of the last lot, soaked for 30 minutes, but 27 percent grew. These variations are so unaccountable and confusing as to vitiate this experiment.

On the other hand, the results of the six plantings of June 28 varied only from 85 to 90 percent, and these results may be fairly accepted. Of 500 kernels dipped in turpentine and planted at once, 90 percent grew; of those soaked for 5 minutes before planting, 88 percent grew; and of those soaked for 20 minutes, 90 percent grew. Of another lot of 500 kernels, soaked first in water for 10 minutes and then merely dipped in turpentine, 90 percent grew; of a second lot treated in the same manner except that they were soaked for 5 minutes in turpentine, 85 percent grew; and the same ratio was obtained from a third lot similarly treated except that the kernels were soaked for 20 minutes in water. This treatment with turpentine may be said, on the whole, to have been apparently without injurious effect, since the check plantings of this date gave a germination average of 89 percent, while the later plantings with turpentine averaged 88 percent to grow.

Tar-water.—Two thousand kernels were planted June 28, after treatment with coal-tar water obtained from the bottom of a gas tank, or from the top of a tank of coal-tar, at the gas works. One thousand of these kernels, merely dipped in the tar-water, gave a germination ratio of 94 percent, and of another thousand soaked in it for 5 minutes, 88 percent grew.

The principal data of the foregoing discussion are summarized in the following table.

PLOT EXPERIMENTS WITH REPELLENTS, 1905

No Treatment of Seed. Check Plots

Date	Treatment	No. of kernels	Percent to grow
June 15	None	200	88
" 28	"	1500	89
" 29	"	200	83
July 21	"	150	95
General average of checks			89

Seed treated with Pure Kerosene

Date	Time in kerosene	No. of kernels	Percent to grow
June 15	Dipped	100	95
" 28	"	1000	97
" 15	5 minutes. Dry	100	88
" 28	" " "	1000	94
" 28	" " Wet	1000	91
" 15	10 " Dry	100	85
" 15	20 " "	100	87
" 15	30 " "	100	82
" 28	30 " Wet	500	81
" 30	11 days	100	89
July 18	20 "	50	86
Aug. 9	41 "	50	80
General average of kerosene treatments			88

Seed treated with Kerosene Emulsion

Date	Percent kerosene	Time in emulsion	No. of kernels	Percent to grow	
June 15	10	30 minutes	100	46	
" 15	20	30 "	100	76	
" 15	40	30 "	100	63	
" 15	50	30 "	100	57	60.5
" 28	10	30 "	500	92	
" 28	20	30 "	500	92	
" 28	40	30 "	500	96	93⅓

Seed treated with Turpentine

Date	Time in turpentine	No. of kernels	Percent to grow	
June 15	Dipped	100	28	
" 15	5 minutes	100	76	
" 15	10 "	100	95	
" 15	30 "	100	27	56.5
" 28	Dipped. Dry	500	90	
" 28	" Wet	500	90	
" 28	5 minutes. Dry	500	88	
" 28	5 " Wet	500	85	
" 28	20 " Dry	500	90	
" 28	20 " Wet	500	85	88

Seed treated with Coal-tar Water

Date	Time in tar-water	No. of kernels	Percent to grow
June 28	Dipped	1000	94
" 28	5 minutes	1000	88

POT EXPERIMENTS, 1906

In all the experiments of 1906, Leaming seed-corn of excellent quality was planted, at a depth of an inch, in good black soil contained in ordinary earthen flower-pots seven inches across, and kept in the insectary of my office building at Urbana. Temperature and moisture conditions, being under strict control, were made as nearly those of a normal spring as possible. Thirty-five check lots of 50 kernels each (1750 kernels in all) were planted with untreated seed in the course of these experiments. Sixteen hundred and eighty of these kernels germinated, and this germination ratio (96 percent) may be used for comparison in determining the effect of our various applications to the seed.

Kerosene.—Kerosene was used in two ways in these experiments: (1) by mixing it thoroly with the seed in quantities varying from 1/6 of a fluid ounce to 3 1/3 ounces for each gallon of corn; and (2) by putting the seed into kerosene and soaking it there, previous to planting, for periods varying from 10 minutes to 19 hours. The main results of these various experiments were as follows:

Of 800 kernels planted after stirring in kerosene thoroly, at rates varying from 1/6 of an ounce to 2 ounces for each gallon of corn, 98 percent germinated, and only 2 of the plants showed any trace of injury. Fifty kernels of this lot, treated at the rate of 2 ounces of kerosene to the gallon, all sprouted, and none of these plants were injured. Furthermore, of 200 kernels treated with kerosene at the rate of 2 1/3 to 3 1/3 ounces to the gallon of corn, 92 percent germinated, and only 3 plants gave any appearance of injury. It would naturally be inferred from this experiment that at least an ounce (two tablespoonfuls) of kerosene to the gallon of corn might be safely used under conditions as favorable as those in our management, but we shall later find evidence, in the outcome of a field experiment made the following spring, that only half this amount injured corn slightly, but still appreciably, under the weather conditions of 1906.

Soaking the corn in kerosene for 10- to 20- minute periods, 200 kernels in each experiment, gave a germination ratio of 88 percent for the first and 93 percent for the second, but with the appearance of injury to 77 percent of the plants in the 10-minute lot and of 80 percent in the 20-minute lot. Furthermore, the plants which grew, averaged only 2 3/4 inches high fifteen days after planting, while 100 plants from untreated seed averaged 6 1/3 inches. The corn would perhaps have outgrown this backset, and might have made a crop, if planted out-of-doors, better than the average in the field, provided that the latter was injuriously infested by the corn root-aphis.

Soaking seed in kerosene for periods varying from 4 hours to 19 hours gave variable results, as reported by Mr. Kelly. Only 1 out of 50 grains (2 percent) soaked for 4 hours had sprouted at the end of thirteen days, while 164 kernels out of 200 (82 percent) which had been soaked for 16 hours before planting, appeared above ground

within six days, 92 percent of the plants finally showing more or less injury. On the other hand, but 3 out of 100 kernels soaked for 19 hours in kerosene were in condition to grow, and all the plants from these 3 were injured.

Perplexing discrepancies of this sort were of rather frequent occurrence in these experiments, and showed that one must apply the results with caution, keeping well within the limits of variation. In view of the observed effect of an overdose of kerosene on the young plant, as described in the earlier part of this article, it is important to note that no dwarfing or distortion of the corn plants was seen in any of these experiments.

Crude Petroleum.—A series of tests made with 600 kernels of corn by soaking them in crude petroleum for various periods ranging from 5 minutes to 74 hours, gave us reason to believe that this substance was too dangerous to be used in this way. No experiments were made, however, with the mere mixture of minimum quantities of petroleum with a gallon of corn. The same variable and discrepant results were reported here as in the experiments with kerosene, 14 kernels growing out of 50, for example, which had been soaked for 30 minutes, and 46 out of 50 which had been soaked for 19 hours. After 5 minutes' soaking, only 42 kernels grew out of 50 planted, and 8 of the plants which appeared were injured.

Oil of Lemon.—A good quality of oil of lemon,* as obtained at a local wholesale drug-store, was used in solution with ordinary alcohol at strengths of 1 part in 10 or 1 part in 3 of the oil to the alcohol. The seed was soaked in these mixtures for periods varying from 5 minutes to an hour. Two plantings were made with kernels treated by stirring 3 ounces of the 10 percent solution thoroly into a gallon of the seed. Of 450 kernels treated in the various ways described, 95 percent germinated with virtually no injury to the plants.

The only damage done to the seed in experiments with this mixture of lemon oil and alcohol appeared in two lots of 50 kernels each soaked in the 10 percent solution, one of them for 20 minutes and the other for 19 hours. In the first of these lots 16 kernels, and in the second lot 21 kernels, failed to grow. It was a perplexing fact that serious injury to the seed was thus reported by Mr. Kelly to have followed the use of a 10 percent solution for 20 minutes, while no harm resulted from a 10 percent solution applied for 30 minutes or for an hour, or from a 33 percent solution applied for 20 minutes or for 30 minutes. It appeared safe to conclude, however, that a 10 percent solution used merely to moisten the seed, say, at the rate of 3 ounces to the gallon of corn, might be applied without risk of injury to the seed; and our field experiments were made, later in the season, on this basis.

Other vegetable oils.—Oil of wintergreen, oil of cloves, and oil of sassafras were tested, each with 400 kernels, divided into eight

*The brand and manufacturer of this sample could not be learned later, when it became important to know just how the results of these experiments were obtained.

experiments. All proved to be too frequently injurious to the seed to make it safe to trust to them—the oil of cloves the most injurious and the oil of wintergreen the least so. Solutions of less than 10 percent strength were not used, however, and no trial was made of any milder form of application than soaking the seed for 5 minutes in an alcoholic solution of the oil. It is possible, consequently, that a simple stirring into the seed of minimum quantities of a 5 or 10 percent solution, as in the case of the oil of lemon, might have been harmless—excepting, however, the oil of cloves, which killed from 44 to 100 percent of the kernels in each experiment.

Carbolic Acid.—The action of carbolic acid was tested by soaking seed-corn from 5 to 30 minutes in solutions of the commercial acid in water, varying in strength from 2 to 30 percent. No injury was done by either 2 or 5 percent solutions applied to lots of 200 kernels each for 5, 10, 20, or 30 minutes, but the 10 and 30 percent solutions killed virtually all the seed even when applied for only 5 minutes. In our subsequent field experiments a 3 percent solution only was used, and then at the rate of 3 ounces of the solution to a gallon of corn.

Formalin.—A few experiments made with formaldehyde, in water solutions of 4 percent, 25 percent, and 50 percent, showed that at 4 percent this substance was harmless to seed-corn soaked in it for any period between 5 minutes and half an hour. Two hundred kernels thus treated gave a germination ratio of 94 percent. The plants which grew, on the other hand, averaged only 4¼ inches at a time when the single check of 50 plants averaged 6 inches. The higher strengths mentioned were both extremely injurious, the 25 percent mixture killing from one fourth to four fifths of the seed, according to the period of use, and the 50 percent mixture, applied for half an hour, killing it all.

The Alcohols.—To distinguish between the effects of alcohol and oils in some of the above mixtures, 200 kernels were soaked in common alcohol for periods ranging from 5 minutes to half an hour, and 200 more in wood alcohol from 5 minutes to an hour, with the result that no injury was done except by the longer periods of treatment. From 98 to 100 percent of the grains grew after soaking 10 or 20 minutes in ordinary alcohol, but only 66 percent after 30 minutes' treatment; and 95 percent grew after 5 or 10 minutes in wood alcohol, but only 74 percent after 20 minutes and 14 percent after an hour. From this it may be inferred that seed-corn is uninjured by as much as 10 minutes' soaking in either kind of alcohol, but that more than this is dangerous, and that injury will begin to appear after 20 or 30 minutes' treatment—sooner if the solvent is wood alcohol.

Lysol.—This highly odoriferous coal-tar product was applied to seed-corn in twenty-one lots of 50 kernels each, and in aqueous solutions of 1 percent, 2 percent, 5 percent, and 10 percent, the corn being soaked in each of these 5 minutes, 10 minutes, 20 minutes, and 1 and 2 hours. Another lot of corn was soaked for 5 minutes in pure lysol, and lysol was applied to seed-corn at the rate of half an ounce

of the fluid to the gallon of corn, and at the rate of an ounce to the gallon. No injury was done by the 1 percent solution applied in periods up to two hours, and the 2 percent solution was harmless up to 20 minutes. Two hours' soaking at the latter strength was injurious, giving a germination ratio of but 68 percent, and all the plants growing were more or less injured. The 5 percent solution did no harm when used for 5 or 10 minutes, but after 20 minutes' treatment only 78 percent of the kernels grew, while after 2 hours' treatment at this strength all the corn was dead. Even 5 minutes' use of a 10 percent solution proved injurious. Corn treated with the pure lysol at the rate of half an ounce to a gallon of the corn was uninjured, 92 out of 100 kernels of it germinating; but when this strength was doubled, the germination ratio fell to 73 percent. From these experiments we may infer that a 2 percent solution of lysol in water may be used to soak the seed if treatment be not continued over 10 minutes, and that half an ounce of the undiluted lysol may be stirred into a gallon of corn without risk of injury.

Kainit.—The potash fertilizer known as kainit, which has sometimes been recommended as a repellent to the corn root-aphis, was tested on 300 kernels divided into six lots. The total germination ratio was 90 percent. One lot, in which the planted seed was thickly covered with kainit, fell to 78 percent.

Lime, Sulphur, and Salt.—Saturated solutions of either lime or salt were harmless to seed-corn soaked in them for 30 minutes or less, and 84 percent of the kernels germinated when planted after rolling in a plaster of wet salt, none of the plants showing injury. Simple powdered sulphur, 1 or 2 pounds to the bushel of corn, had no effect upon the seed, however it was applied; neither did mixtures of lime, sulphur, and salt, or lime, sulphur, and blue vitriol, unless these were applied for more than an hour. After 2 hours' soaking in a solution of lime and sulphur (15 pounds of each to 50 gallons of water), seed-corn sprouted in a ratio of 80 percent, with an appearance of injury to all the plants which grew. A ready-prepared solution of sulphur sold under the name of "Rex Dip" was variously used in the treatment of seed-corn, and in every case without noticeable effect on the germination of the seed until this had been soaked in it for more than an hour. Seven hundred kernels divided into fourteen lots of 50 each and soaked for periods varying from 5 minutes to an hour gave a general germination average of 96 percent, 4 percent more than the normal for untreated corn of this sample. Two hundred kernels planted in four lots of 50 each, and soaked for 2 hours, gave a ratio of 88 percent of kernels germinating.

Chlorid of Lime.—Used in a saturated solution, or applied by rolling the kernels in a wet plaster, chlorid of lime was without effect on the sprouting of the seed or the growth of the plants. Two hundred kernels soaked for 5 to 30 minutes in the solution grew in a ratio of 98 percent, and 100 kernels rolled in a thin paste of the wet lime all grew. Dry chlorid mixed with the seed was also harmless to 50 kernels.

Carbon Bisulphid.—A carbon bisulphid treatment was also harmless so far as tested by stirring the undiluted fluid into the corn at the rate of 2 and 4 ounces per gallon, or by soaking the seed in the fluid for 10 minutes.

Copper Sulphate.—Seed-corn soaked in a saturated solution of blue vitriol was uninjured after 5 and 10 minutes' treatment, and 90 percent of the seed germinated after 20 minutes' soaking, but only 83 percent after 30 minutes (16 percent of the plants being injured) and 80 percent after an hour, all of these last plants showing injury.

Iron Sulphate.—Two hundred kernels of seed-corn soaked in a saturated solution of copperas for periods varying from 5 minutes to 16 hours, and in lots of 50 kernels each, were uninjured as to germination, averaging 95 percent.

Tobacco-water.—Strong solutions of tobacco-water, obtained by boiling the stems, did no injury to seed or plant, even when the corn was soaked from 1 to 24 hours. Three hundred and fifty kernels thus treated, 100 of them for the longer period, gave an average germination ratio of 98 percent.

Musk.—Commercial Tonquin musk, mixed with wood alcohol at the rate of 1 part of musk to 10 of the solvent, did no injury to the seed when 3 ounces of the mixture were thoroly stirred into a gallon of corn. Neither a 5 percent nor a 10 percent solution of the musk in ordinary alcohol injured the seed after 5 minutes' soaking, but a longer exposure diminished the ratio of germination, and soaking for an hour was decidedly injurious. These effects were, however, quite possibly due to the alcohol.

Mustard.—Mustard was injurious when applied in the powdered form, but 16 hours' soaking in a saturated solution with water did not affect germination.

Miscellaneous substances.—The proprietary insecticides "Scalecide," "Con Sol," "Calcothion," and "Frutolin" were all without effect upon the seed, tested by soaking the seed in them for 5 to 30 minutes. "Scalecide" was used in 5 and 10 percent mixtures with water, "Con Sol" in a 2½ percent mixture, and "Calcothion" and "Frutolin" pure. Twenty lots, amounting to 1000 kernels, were soaked in these various insecticides, none giving less than a germination ratio of 92 percent, and most of them rising to 98 and 100 percent.

Fifty kernels of corn left in coal-tar for a minute and planted at once, all grew but one—very slowly, however, and with more or less appearance of injury, the plants averaging only 3⅓ inches in height four weeks after planting. Soaked in coal-tar for 16 hours, only 11 kernels grew out of 50, and the plants from these were all stunted and otherwise injured.

Tar-water, obtained by pouring water upon coal-tar and stirring the two together and leaving for a time to settle, did no injury to 50 grains of seed soaked for half an hour or an hour.

Camphor was imperfectly tested by soaking seed-corn for 10 minutes and for an hour in a saturated solution of the gum in alcohol.

After 10 minutes' soaking all the seed grew, but after one hour's treatment all but 2 kernels out of 50 were killed. A light application of the solution at the rate of about 3 ounces to the gallon of corn produced no effect, 49 kernels out of 50 growing, and the plants being uninjured and of maximum height after 3 weeks.

The more important of these statistical data are brought together in the table following.

PRINCIPAL POT EXPERIMENTS WITH REPELLENTS, 1906

No Treatment of Seed. Check Pots

	No. of kernels	Percent to grow
No treatment	1750	96

Treatment of Seed with Kerosene

Quantity or time	No. of kernels	Percent to grow
⅛ oz.—2 oz to one gallon	800	98
2⅓ oz.—3⅓ oz. to one gallon	200	92
10 minutes' soaking	200	88
20 " "	200	93
4 hours' "	50	2
16 " "	200	82
19 " "	100	3

Treatment of Seed with Crude Petroleum

Time in petroleum	No. of kernels	Percent to grow
5 to 10 minutes	100	91
20 to 30 "	100	56
1 to 3 hours	150	77
19 to 74 "	250	54

Treatment of Seed with Oil of Lemon and Alcohol

Quantity or time	No. of kernels	Percent to grow
Oil of lemon, 10% mixture:		
3 oz. to gallon of corn	100	98
20 to 60 minutes' soaking	150	87
19 hours' soaking	50	58
Oil of lemon, 33⅓% mixture:		
5 to 10 minutes' soaking	100	99
20 to 30 " "	100	99

Treatment of Seed with Solutions of Carbolic Acid

Strength	Time	No. of kernels	Percent to grow
2 percent	5 to 30 minutes	200	99
5 "	5 to 30 "	200	96
10 "	5 to 30 "	200	9
30 "	5 to 30 "	200	1

Treatment of Seed with Formalin Solutions

Strength	Time	No. of kernels	Percent to grow
4 percent	5 to 30 minutes	200	94
25 "	5 minutes	50	74
25 "	10 to 30 minutes	150	34
50 "	30 minutes	50	0

Treatment of Seed with Alcohol

Time in alcohol	No. of kernels	Percent to grow
Common alcohol:		
5 to 20 minutes	150	98
30 minutes	50	66
Wood alcohol:		
5 to 10 minutes	100	95
20 minutes	50	74
60 "	50	14

Treatment of Seed with Lysol in Water

Strength	Time or quantity	No. of kernels	Percent to grow
1 percent	5 to 120 minutes	200	99
2 "	5 to 20 "	150	95
2 "	2 hours	50	68
5 "	5 to 10 minutes	100	96
5 "	20 minutes	50	78
5 "	2 hours	50	0
10 "	5 to 10 minutes	100	78
10 "	20 to 60 "	100	0
100 "	5 minutes	50	2
100 "	1 oz. to gal. corn	100	73
100 "	½ oz. to gal. corn	100	92

A CORN-FIELD EXPERIMENT, 1906

Precautions preliminary to a large field experiment having been thus taken, and injury to the seed thus guarded against, the way was open to a practical test of the most promising of these repellents, to be made by planting parts of the same field with corn treated with each of them, leaving other parts untreated as a check.

THE EXPERIMENTAL FIELD

For this purpose, after a careful examination of many fields in the vicinity of Elliot, Ford county, by one of my assistants, Mr. E. O. G. Kelly, choice was made of twenty acres of dark rich loam, level and of a uniform quality, on the farm of Mr. James Jones, one and a half mile northeast of Elliot.

This ground had been in corn the preceding year, and it was heavily infested by the corn-field ant. The old stalks were harrowed down and burned April 24 and 25, and the field was plowed to a depth of 4 to 6 inches April 26 to 28, with a gang of two plows, each cutting a furrow 15 inches wide. It was then twice harrowed with a toothed harrow—the last time May 7—and was planted May 8 to 11, in rows 80 rods long, 372 hills to the row, the hills 3½ feet apart each way.

INSECT INFESTATION OF FIELD

A number of ants' nests in this field, critically examined previous to April 26, all contained eggs and recently hatched young of the corn root-aphis. The degree of infestation of the field was ascertained by counting the nests of the corn-field ant overturned by the plow. Eleven hundred and forty-two nests were found in 62 furrows crossing the field and aggregating 15½ miles in length. This was at the rate of 74 ants' nests to the mile of furrow, 516 to the acre, or 10,320 to the entire field.

Nineteen days later 250 hills of the corn in the check plots of this field were found to harbor an average of 62 ants to the hill,—equivalent to nearly five millions in the entire field; and within six weeks from the time of planting, the check hills averaged 162 root-lice,—equivalent to twelve and a half millions of those insects to the field.

Even this statement does not fully describe the burden of infestation with which our experimental field began the year. During his tramp of 15½ miles, backward and forward behind the plow, Mr. Kelly counted also 6519 white-grubs exposed in plowing, which is at the rate of nearly 3000 of these destructive insects to the acre, or 59,000 for the entire field. Of course only a small part of the grubs in the soil were brought to view by the plowing, and this number may reasonably be trebled or quadrupled for an estimate of the whole number present.

DESCRIPTION OF THE EXPERIMENT

The ground being thus selected, found thus infested, and made ready for planting, an experiment was started May 9 with four principal substances—kerosene, oil of lemon, formalin, and carbolic acid—and with three others, to which less importance was attached—flowers of sulphur, chlorid of lime, and "Rex Dip." The experiment was laid out as follows:

The first 50 rows from the east side of the field were planted with corn not treated, and available, consequently, as a check. The next 24 rows were planted with seed treated with a 3 percent solution of

crude carbolic acid in water. Three ounces of this mixture was poured upon a gallon of corn, which was thoroly stirred until every kernel was moistened, the surplus being allowed to drain away. Notwithstanding its slightly moist condition, the corn ran out of the planter as well as if it had been dry.

The 20 rows next this strip were planted with ordinary seed left as a check; and for the next 12 rows the corn was treated with kerosene, half a fluid ounce of the pure oil being thoroly mixed with a gallon of the seed just before it was put into the box.

The next 12 rows were planted with corn treated with oil of lemon. For this purpose one part, by measure, of the oil was mixed with nine parts of ordinary alcohol, and 3 fluid ounces (6 tablespoonfuls) of this solution was thoroly stirred into a gallon of corn, which was then drained and put at once into the planter box.

The next 8 rows were left as a check; and for the plot of 12 rows adjoining, the seed was treated with formalin reduced to a 3 percent solution by the addition of water. Three ounces of this mixture was thoroly stirred with a stick into a gallon of corn, which was then carefully drained and put into the planter at once.

On the 11th of May, in another part of the field, 28 rows of corn were planted, the seed for which had been treated with a solution of lime and sulphur known as "Rex Dip," 1 part of this substance to 10 parts of water. A pint of the mixture was poured upon a gallon of seed-corn, which was then thoroly stirred, and after 20 minutes' soaking the seed was drained, being stirred in the meantime to dry it partially, in order that it might work well in the planter.

Next to this plot, a strip of 8 rows was left as a check, and the following 8 rows were planted with corn treated with flowers of sulphur. The grain was dampened slightly to make the sulphur stick, and a quarter of a pound of the latter was stirred thoroly into a gallon of corn, completely covering all the kernels.

Finally, 16 rows adjacent were planted with seed which had been soaked for 10 minutes in half a pint of a saturated aqueous solution of chlorid of lime to the gallon of corn.

The ground was reported to be very dry at the time of planting, and the young weeds in the field were all dead as a consequence. Its condition was evidently not unusual, however, since a heavy rain is recorded for May 2, and another followed May 8.* Nevertheless there was some deficiency of moisture, for the soil was lumpy after plowing, and the sprouting of the seed was said, on the 22d, to have been delayed somewhat by dry weather.

Fifty hills of corn were examined on the latter date in one of the checks, and 15 were found to contain root-lice and ants. Odors of carbolic acid, oil of lemon, and kerosene were still perceptible on the kernels a week after planting, but the corn treated with formalin had no noticeable smell.

*Rains fell at this place as follows: April 8, 13, 24, 30 (shower); May 1, 2 (heavy), 8, 18 (slight), 26 (heavy), 27, and 30. The fields and roads were said to be muddy June 1.

RESULTS OF THE EXPERIMENT. FIRST INSPECTION

The first general inspection of the field was made by Mr. Kelly May 28 to 30, when 800 hills were dug up in the various plots and the ants and root-lice were carefully counted.* Two hundred and fifty of these hills were from the check plots, 100 each from the principal experimental plots—those with carbolic acid, kerosene, formalin, and oil of lemon—and fifty each from the three remaining plots whose seed had been treated with sulphur, "Rex Dip," and chlorid of lime.

Percentages of hills infested 19 days after planting.—At this time, a month after the plowing of the field and 19 days after planting, 57 percent of the 250 hills dug up in the check plots were infested by ants. The corresponding averages for each of the four principal experimental plots were as follows: oil of lemon, 23 percent infested; kerosene, 31 percent; formalin, 33 percent; and carbolic acid, 49 percent. The ratios for the less important experiments, from each of which 50 hills were dug up, were 54 percent for the sulphur plot, 70 percent for the "Rex Dip," and 48 percent for the chlorid of lime. Otherwise stated, using the condition of the check plot as a basis of comparison, the plot treated with the oil of lemon showed an improvement of 60 percent in number of hills infested by ants; the kerosene plot, a 46 percent improvement; the formalin plot, 42 percent; and the carbolic acid plot, 14 percent. The three other plots showed no improvement except possibly the chlorid of lime.

Not all the hills containing ants at this time contained root-lice also, but there were no root-lice where there were no ants. The ratios of infestation of corn hills by the root-aphis for the five plots were as follows: checks, 53 percent; oil of lemon, 14 percent; kerosene, 20 percent; formalin, 28 percent, and carbolic acid, 39 percent. The corresponding ratios of improvement in respect to aphis infestation were these: oil of lemon, a benefit of 74 percent; kerosene, 62 percent; formalin, 47 percent; and carbolic acid, 26 percent.

It is a suggestive fact that while the infested hills of the checks contained an average of 21 ant larvæ to the hill, none of the hills treated with the three most odorous substances, oil of lemon, kerosene, and carbolic acid, contained so much as a single larval ant. In the formalin plot, however, there were about as many larvæ to the infested hill as in the checks. As the ants take assiduous and anxious care of their young, the absence of larvæ from the treated hills, even where the workers themselves were numerous, is evidence that conditions there were offensive to the ants.

In view of the observed effect of an overdose of kerosene on the young plant, as described in the earlier part of this article, it is important to note that no dwarfing or distortion of the corn plants was seen in any of these experiments.

Average numbers of insects 19 days after planting.—Turning now to the number of both kinds of insects in these plots, irrespective of

*The owner of this field was paid at an agreed rate for all hills dug up or injured in the course of our experiments.

the number of hills of corn infested by them, we find an average of 66 ants and 23 root-lice to the hill in the checks, 9 ants and 2 root-lice to a hill in the oil of lemon plot, 16 ants and 3 root-lice in the kerosene plot, 30 ants and 6 root-lice in the formalin plot, and 25 ants and 12 root-lice to the hill in the plot treated with carbolic acid. The ratios of benefit in respect to the numbers of root-lice were consequently as follows. With respect to ants: oil of lemon, 86 percent benefit; kerosene, 76 percent; formalin, 55 percent; and carbolic acid, 62 percent. With respect to root-lice: oil of lemon, 83 percent benefit; kerosene, 87 percent; formalin, 74 percent; and carbolic acid, 52 percent. The use of the three secondary applications, on the other hand, "Rex Dip," chlorid of lime, and sulphur, had evidently accomplished comparatively little. In the plot treated with chlorid of lime there were 31 ants and 25 aphids to the hill; in that treated with sulphur, 45 ants and 31 aphids; and in the plot treated with "Rex Dip," 72 ants and 53 aphids—the last two of these numbers being actually greater than those for the checks.

The total normal infestation of this field at this time, as shown by the condition of the checks, was 240,000 ants and 124,000 root-lice to the acre. The aphids were all in hills of corn, while only so many of the ants were there established as was necessary to the purposes of the colony, the central home of which was commonly outside the hill between the rows of corn. The data of the foregoing discussion are briefly presented in the tables on page 20.

RESULTS OF THE EXPERIMENT. SECOND INSPECTION

June 21, 43 days after planting, a second count was made of both ants and aphids in 250 hills—50 hills each for the check and for the four principal experimental plots. At this second counting, 73 percent of the hills in the check were infested with ants, 22 percent of those in the oil of lemon plot, 44 percent in the kerosene plot, 46 percent in the formalin plot, and 76 percent in the plot treated with carbolic acid. A few hills contained ants which did not contain root-lice also. The corresponding ratios of infestation by root-aphids for these five plots were as follows: check, 73 percent; oil of lemon, 20 percent; kerosene, 40 percent; formalin, 46 percent; carbolic acid, 74 percent. In respect to number of insects in each lot of 50 hills dug from the various plots, we find the difference quite as marked. The check plot contained 39 ants and 166 aphids to the hill; the oil of lemon plot, 8 ants and 18 aphids; the kerosene plot, 16 ants and 52 aphids; the formalin plot, 20 ants and 64 aphids; and the carbolic acid, 32 ants and 139 aphids.

Converting these data into percentages of improvement, by comparing the ratios for each experiment with those of the check, we find that the benefit to the plot treated with oil of lemon was 70 percent in number of hills infested by ants, 73 percent in hills infested by aphids, 79 percent in the number of ants in the plot, and 89 percent in the number of aphids. The corresponding ratios of benefit for the

kerosene plot are 40 percent in hills infested by ants, 45 percent in those infested by aphids, 59 percent in number of ants, and 69 percent in number of aphids. In the formalin plot the benefit for hills infested by ants and by aphids was 37 percent for each, and the benefit in number of ants in the plot was 49 percent, and in number of aphids, 61 percent. In the carbolic acid plot, on the other hand, the numbers of hills infested by ants and by aphids were somewhat larger than in the check.

INSPECTIONS OF MAY AND JUNE, 1906

Percent of Hills infested

	Check	Oil of lemon	Kerosene	Carbolic acid	Formalin
By ants:					
After 19 days	57	23	31	49	33
After 43 "	73	22	44	76	46
By aphids:					
After 19 days	53	14	20	39	28
After 43 "	73	20	40	74	46

Insects to the Hill

	Check	Oil of lemon	Kerosene	Carbolic acid	Formalin
Ants:					
After 19 days	66	9	16	25	30
After 43 "	39	8	16	32	20
Aphids:					
After 19 days	23	2	3	12	6
After 43 "	166	18	52	139	64

Percentages of Benefit from various Treatments

	Benefit in hills infested				Benefit in No. of insects			
	After 19 days		After 43 days		After 19 days		After 43 days	
	By ants	By aphids	By ants	By aphids	Ants	Aphids	Ants	Aphids
Oil of lemon	60	74	70	73	86	83	79	80
Kerosene	46	62	40	45	76	87	59	69
Carbolic acid	14	26	00	00	62	52	18	15
Formalin	42	47	37	37	55	74	49	61

FIRST AND SECOND INSPECTIONS COMPARED

Comparing next the conditions found May 28 and June 21, we find that the number of hills infested in the check had increased between these dates from 57 percent to 73 percent for ants, and from 53 percent to 73 percent for the aphids; while the number of ants to the hill had diminished from 66 to 39 and the number of aphids to the hill had increased from 23 to 166. The number of the aphids, it will be seen, had increased sevenfold.

Rate of increase of root-lice in the field.—The period of active multiplication of the root-aphis in the field commonly continues until early October, approximately six times the period within which we found a sevenfold increase. If this rate of increase were maintained until the end of the season, the 124,000 aphids per acre found May 28 would multiply by October 1 to more than 14,340,000,000, or 39,000 to the hill of corn. This computation of the actual rate of multiplication of the corn root-aphis in the field is sufficient to account completely for any amount of injury which these insects may do to the crop under conditions favorable to their increase.

RESULTS OF THE EXPERIMENT. THIRD INSPECTION

On the 17th of July Mr. Kelly reported a conspicuous difference in height between the corn on the experimental strips and that on the checks—a difference so great, indeed, that as one looked across the field, it seemed to lie in alternate ridges and hollows, the ridges corresponding to the experimental strips and the hollows to the checks. The ground being perfectly level, these differences were evidently due to the more rapid growth of the corn in the experimental plots; or, more correctly speaking, to an arrest of growth in the checks resulting from the greater drain of insect injury where the corn had not been protected by a previous treatment of the seed. Visiting this field July 21, I noticed that the central rows of the check strips were shortest, and the central rows of the experimental strips were tallest, the transition from one to the other being gradual. On passing down a central check row, the highest stalks reached, on the average, to my elbows; and on walking down the central row of an experimental strip, the tallest stalks were found to reach nearly to the top of my head.

To verify this observation, measurements were made of the tallest stalks in 214 hills of one of the checks, and in 157 hills of the carbolic acid plot. The first of these averaged 36 inches and the second 62 inches. The height of the corn in the check strip was less by 42 percent than that in the experimental plot, and this was the measure of an injury by insects in the former which had been prevented in the latter by the treatment of the seed. This striking difference was quite as obvious to the eye August 27, after all the corn had tasseled.

RESULTS OF THE EXPERIMENT. FOURTH INSPECTION

What proved to be a final inspection of this field was made September 20, when the hills and both fertile and barren stalks were

counted in six rows of the checks and in three rows each of the four experimental plots.

Number of hills of corn to the row.—The following were the average number of hills of corn to the row 372 hills long. In the check, 329½ hills; in the carbolic acid plot, 328; oil of lemon, 326; formalin, 317; kerosene, 282. In other words, 11.4 percent of the places for hills were without corn in the check, 11.8 percent in the carbolic acid plot, 12.4 in the oil of lemon plot, 14.7 percent in the formalin plot, and 24.2 percent in the plot treated with kerosene. The differences between the check on the one hand and the plots treated with carbolic acid and oil of lemon on the other are doubtless insignificant, and perhaps the formalin plot should be included in this statement. Considerable importance must be attached, however, to the fact that more than twice as many hills were missing in the plot treated with kerosene as in the check, *three* rows of the kerosene plot containing 271 missing hills as against 255 missing from *six* rows of the check. In view of the injurious effect of kerosene upon the seed, as shown by our insectary work and by our field experiment of 1905, we can only suppose that some injury was done even by the minimum amount of kerosene used in this experiment of 1906.

Number of stalks of corn to the row.—The number of stalks to the row in these various plots was as follows: check, 621; oil of lemon, 641; formalin, 545; carbolic acid, 543; kerosene, 511. The plot treated with the oil of lemon, it will be noticed, contained 20 stalks more to the row than the check—an increase of 3.2 percent, apparently due to a complete destruction of the plants by the insects in the check, against which the experimental strip had been protected by its treatment. In the remaining plots, on the other hand, the number of stalks was diminished in the experimental plots from 12.2 percent in the formalin strip to 17.5 percent in the kerosene—a diminution which can only be accounted for on the supposition that a certain amount of the seed was injured by these substances. Indeed, taking as a basis of comparison the number of stalks in the plot planted with seed which had been treated with oil of lemon, we find the loss of plants in the kerosene strip to have been 20 percent and that in the other plots to have been approximately 15 percent—all due, so far as one can see, to injury to the seed by the substances employed.

Ear-bearing stalks to the row.—The most significant comparison of these plots was made by a count of the stalks bearing ears, the number of barren stalks varying greatly according to the treatment applied. In the check plot were 412 ear-bearing stalks to the row; in the oil of lemon plot, 526; in the carbolic acid plot, 505; in the formalin plot, 485; and in the kerosene plot, 439,—all four numbers considerably larger than those of the check. The greatest improvement to be seen in this final test of treatment is in the oil of lemon plot, where the yield in ear-bearing stalks was 27.7 percent greater than that of the check, the corresponding ratios of increase for the remaining plots being as follows: carbolic acid, 22.6; formalin, 17.7;

kerosene, 6.6. It will be noticed that notwithstanding the fact that the kerosene plot contained an average of 110 stalks per row fewer than the check, the number of ear-bearing stalks was 27 per row greater than in the check. Even the kerosene, tho it seemed to have lessened the stand by an injury to the seed, had increased the yield nearly 7 percent by protecting the corn against the drain of root-louse attack, thus preventing the blighting of a considerable percentage of the remaining stalks. Under the conditions present during this season and in this field, all these treatments had an ultimate beneficial result, according to the data thus repeatedly and carefully collected, the actual ratio of benefit being, however, nearly four times as great from the use of the oil of lemon as from the use of kerosene.

INSPECTION OF SEPTEMBER 20

	Check	Oil of lemon	Carbolic acid	Formalin	Kerosene
Hills to the row.....	329.5	326	328	317	282
Stalks to the row.....	621	641	543	545	511
Fertile stalks to the row	412	526	505	485	439

Thru an unfortunate failure of the tenant farmer controlling this field, I was disappointed in my original plan to harvest the plots separately, measuring and weighing the product of each in comparison, and the difference in yield, apart from these differences in number, can only be inferred from Mr. Kelly's note of September 20, which reads: "The ears and the stalks in the checks were very small, much smaller than on any of the treated plots. The ears and stalks in plots treated with oil of lemon and carbolic acid were much larger than those in the other treated plots, and much larger than in the checks."

GENERAL FINAL RESULT

As a final statement of the most important result of the various treatments of seed-corn here described, it may be said that, according to the data of this experiment, the oil of lemon treatment increased the yield 1159 ear-bearing stalks to the acre; the carbolic acid treatment, 945 such stalks; the formalin treatment, 742; and the kerosene treatment, 274.

The expense of all the treatments was trifling, that of the most costly—the oil of lemon—amounting to about ten cents an acre for material used.

COMPARISON OF INFESTED FIELDS

That the infestation of this field altho heavy enough to reduce the yield by at least one third, was not by any means extreme is shown by conditions reported by Mr. Kelly from a field of 20 acres on another farm near Elliot, as shown by an inspection made September 14. This latter field was so heavily infested by the corn root-aphis that the

crop was virtually destroyed. In a plot of 2000 hills were 2467 stalks, of which 95 percent were less than 4 feet high, and 75 percent were 20 inches high or less. In this entire plot were only 95 ears—a number equivalent to 169 ears to the acre—and these were mainly nubbins. Eleven hundred and thirty-eight hills contained still living plants, and in 1093 of them the root-aphis was still present. Four hundred and sixteen hills which were either dead or withered, dry, and barely living, all contained the root-aphis at the time, or showed by the burrows of ants along the roots that they had been previously infested. In a neighboring field practically uninfested, with which this is to be compared, 2000 hills contained 4324 well-grown stalks with 4024 ears, only 201 of which were nubbins.

MORE EXPERIMENTS NECESSARY

Our field experiment of 1906, decisive as it seems, is, of course, to be taken as applying exactly only to similar, if not identical, conditions—a similar soil similarly prepared, equally infested with the corn root-aphis, and subject to similar weather conditions—and with a treatment of seed identical with ours in all particulars, including materials of the same quality and strength. How far the results here described may be expected to apply to a different soil, less heavily, or even much more heavily, infested, more thoroly prepared, and planted during either a very wet spring or a very dry one, with a less perfect seed, treated with slightly different chemicals and compounds, can be learned only by repeated and varied experiment. Indeed, the possibilities of useful experiment with this method are almost innumerable, and can scarcely be exhausted by any one office, however well manned and equipped, and however long its program of operations. The procedure is so simple and so inexpensive, however, that any careful corn grower can test it, and its usefulness in ordinary practice must be finally determined by such general, careful, and oft-repeated trial as farmers themselves may think it worth while to make. It is my purpose to test it by similar operations in several successive years, the results of which will be reported in later articles of this series, and it will greatly help us to an early practical conclusion if others interested will experiment carefully, and report upon their methods, materials, and results.

AN ADDITIONAL, MINOR TEST

Further special tests on the reactions of ants to the various repellents of our list were made by planting, close around burrows of these ants in the field, a few hills of corn, one of which was left untreated as a check, the remainder being treated with one of the repellents as a test. "Rex Dip," formalin, carbolic acid, oil of lemon, kerosene, chlorid of lime, sulphur, and common lime were tested in this way. The hills so planted were thus immediately exposed to infestation, and any failure of the ants to occupy them would be particularly significant. The test plantings were all made by Mr. Kelly April 5,

in a field near Elliot, and the results were ascertained April 22, when the corn was from 3 to 5 inches high. All the test hills surrounding the ants' nests, including both check and experimental plantings, were thoroly infested by ants and root-lice where the seed had been previously treated by rolling it in lime or sulphur, by soaking for 10 minutes in a saturated solution of chlorid of lime, and by soaking for 10 minutes in a 10 percent mixture of the "Rex Dip." In the lime experiment, 5 hills were planted immediately surrounding an ant's nest, one of these being reserved as a check; in the sulphur experiment, 4 hills were so planted; and in that with chlorid of lime, 4 hills. In that with "Rex Dip," 7 hills were planted around 2 separate nests of the ant. The results of these experiments thus agree with those of our more general test of plot plantings in the field.

As a test of the formalin treatment of the seed, 2 ants' nests were surrounded by 7 hills of corn, 3 around one and 4 around the other. In each case one of the hills was planted with untreated seed, and the seed for the others was soaked in a 4 percent solution of formalin,—for those around one nest for 5 minutes, and for those around the other for 10 minutes. After 17 days, both check and experimental hills were all completely and uniformly infested by the ants.

In an experiment with the oil of lemon, 4 hills were planted around another ant nest, three of them with treated grains and one as a check. Here also all the hills were infested May 22.

In a corresponding experiment with kerosene, 10 hills were planted so as immediately to surround 2 nests of the ants, two of these hills being reserved as checks and the other eight planted with corn which had been moistened with kerosene by putting a single drop to a dozen grains and rolling these together until all were oily. By the 22d of May one of these nests was completely abandoned by the ants, which had apparently formed another nest about three feet away. There were no aphids on roots of either check or experimental hills. The other nest was still occupied, and there were a few aphids on the roots of the check, but none of either ants or aphids on the experimental hills.

Finally, two nests were surrounded by 8 hills, 6 of which had been treated with a 3 percent solution of carbolic acid—in the one case soaking for 5 minutes and in the other for 10. In the former case the roots of the check hill were covered with root-lice attended by a few ants, while those of the three experimental hills had neither ants nor aphids on them. In the latter case the ants had abandoned their nest, and neither checks nor experimental hills were infested.

These results differ, it will be seen, from those of the plot plantings in the fact that, while carbolic acid and kerosene apparently kept the insects out of the treated hills for three weeks, oil of lemon and formalin, as well as a number of other substances tested, were without effect.

GENERAL PROGRAM OF PREVENTION

In the light of what we now know concerning the corn root-aphis, the following measures of precaution are to be recommended as a practical program.

1. *A short rotation period in corn, especially during relatively dry years.* A single year in corn is better than two years, and a period of two years is better than one of three. Especially if the crop was visibly injured by the root-aphis the preceding year, or if more than twenty ants' nests to the mile are turned up by the plow, it is best that the field should be put into some other crop than corn—which other is a matter of indifference, since no other is liable to injury by the corn root-aphis.

It must be remembered, however, that even a field in corn for the first time may become infested during the season by means of winged root-lice coming into it from other fields in its neighborhood, this infestation perhaps beginning as soon as the corn is up; and that the rate of multiplication of these insects is so enormously rapid, under favorable conditions, that such a new infestation sometimes reaches destructive numbers before the first season is over. Even the shortest rotation is consequently not a complete preventive where the root-aphis has become so generally prevalent as it now is in most parts of the Illinois corn belt. This is, however, the most reliable of all known measures of prevention, and has the very great additional advantage that it affords complete protection against another of the great insect pests of the corn field, the notorious northern corn root-worm (*Diabrotica longicornis.*

2. *A deep, thoro, and repeated stirring of old corn ground in fall or spring (or, better still, in winter, where possible) as a preparation for corn-planting.* So quick a rotation as that advised in the preceding paragraph is perhaps not always practicable, and is at any rate often unwelcome and will not always be practiced. If corn is to be planted on ground more or less infested by the root-aphis the preceding year, injury by this insect may be greatly diminished by such a preparation of the soil as will repeatedly break up the underground nests of the ants and scatter the contents of these nests, consisting of the eggs and young of the ants together with the root-lice and their eggs, thoroly and repeatedly thru the dirt. The burrows of these ants do not often reach to a depth of more than six inches, and if plowing to this depth is followed by a deep stirring of the ground with a disk harrow, or better, with a corn cultivator set into the ground as far as possible, the attempts of the ants to recover their propery and to reconstruct their nests are greatly disturbed and rendered largely fruitless. The more thoroly, frequently, and deeply the ground is stirred in the interval between the first plowing and the corn-planting, the fewer will be the root-lice in the field in the beginning of the season. By this means a check will also be placed upon the increase of the ants themselves, by the destruction of their helpless maggotlike young which they have brought thru the winter in their nests. Furthermore, the

young weeds in the field on which the root-lice are dependent for food until the corn begins to grow may thus be so thoroly destroyed as to result in the starvation of the insects. Fortunately the labor of this treatment of the field will usually be more than repaid by an improvement of the corn crop independent of all protection against aphis injury, this being practically the preparation for corn especially recommended by our best teachers of high-grade agriculture and practiced by some of our most successful corn farmers.

It should be clearly understood, however, that this measure will not destroy all the root-aphids in the field. In a few cases ants' nests will go so deep that a part of their contents will be undisturbed by the plow, and will thus remain as centers of infestation from which the ants and aphids spread later to reoccupy the field. Furthermore, the corn-field ant, even under these difficult and discouraging conditions, will sometimes search out and bring together again at least a part of the scattered contents of its burrows.

The outcome of several carefully conducted experiments with this cultivation method of preventing the root-louse injury, is given in Bulletin 104 of the Illinois Agricultural Experiment Station, pp. 102–123, and also in the Twenty-fourth Report of the Illinois State Entomologist, pp. 8–29.

3. *The maintenance and increase of the fertility of the soil.* The richer the ground and the more thrifty the crop the less, other things being equal, will be the injury to plants by the root-louse. We have no present evidence that these insects thrive any the less or multiply any less rapidly on the thrifty corn plant than on one poorly nourished, but there is, of course, no doubt that the plant itself suffers most under insect attack when it has least surplus of vigor and sap to spare. In this respect also, the corn root-aphis helps to enforce the teachings of a better agriculture, increasing the penalty of a poor management by still further diminishing the yield of a deteriorating soil.

4. Finally, *the use of repellents on the seed as described in this paper.* This is still an experimental measure, and evidently can not be commonly relied upon until we know more of its general and average results. It seems to me desirable, however, that a considerable plot should be planted each favorable year in each suitable field, with seed treated by one or the other of the odoriferous repellents here discussed, or, still better, perhaps, by one of the strongest-smelling fertilizers, to be applied by means of a fertilizer dropper; and that the consequences of this treatment should be carefully studied by a comparison of the product of this plot with that of adjacent parts of the field. By a favorable year is meant one in which the spring is of a fairly average character—a little drier than normal, perhaps—and in which, consequently, the seed is likely to grow quickly and the plant to get a good and early start. By a suitable field is meant one in corn for a year or more preceding, and in which nests of the corn-field ant are turned out in plowing at the rate of some fifty or sixty to the mile

of furrow. If they are fewer than this it may be that, in a year favorable for corn, no sufficient injury to any of the plants will be done by the root-lice to make any noticeable difference between corn growing from treated and from untreated seed.

As a safeguard against possible injury to the kind of seed one is using by the kind of materials one may chance to purchase, and in view especially of the well-known differences in seed and the differences also in materials of chemical manufacture, each experiment should be preceded by a seed-corn test, made in the usual form but in a way to bring into comparison treated and untreated seed with respect to the percentage of kernels to grow. In this way the possible failure of an experiment and some loss of stand may be prevented.